AIR FORCE
PROPOSAL PREPARATION INSTRUCTIONS

The responsibility for the implementation and management of the Air Force STTR Program is with the Air Force Research Lab, Wright-Patterson Air Force Base, Ohio. The Air Force STTR Program Manager is Steve Guilfoos, (800)222-0336. **DO NOT** submit STTR proposals to the AF STTR Program Executive under any circumstances. Addresses for proposal submission and numbers for administrative and contracting questions are listed on the following page

Technical questions may be requested using the DTIC SBIR Interactive Technical Information System (SITIS). For a full description of this system and other technical information assistance available from DTIC, please refer to section 1.5c of this solicitation.

The Pre-Solicitation Announcement (PSA), listing the full descriptions of the topics and the author of each, was issued electronically and in hard copy, after being announced in the Commerce Business Daily. Contact the AFOSR directly for information on future PSAs (see mailing address and phone number on the next page). Open discussions can be held with topic authors until 1 Mar 00 concerning technical aspects of topics. Small businesses that did not know about the PSA or did not participate in the exchange may find relevant questions or comments from these talks listed in SITIS, please refer to section 1.5c of the solicitation.

For each Phase I proposal, send one original and three (3) copies to the office designated on the following page. Be advised that any overnight delivery may not reach the appropriate desk within one day.

Unless otherwise stated in the topic, Phase I will show the concept feasibility and Phase II will produce a prototype or at least show a proof-of-principle.

Air Force Fast Track

Detailed instructions on the Air Force Fast Track and Phase II proposals, consistent with this solicitation (see Sec. 4.3 and 4.5), will be given out by the awarding Air Force directorate along with the Phase I contracts.

PROPOSAL SUBMISSION INSTRUCTIONS

TOPIC NUMBER	ACTIVITY/MAILING ADDRESS	CONTRACTING AUTHORITY
	(Name and number for mailing proposals and for administrative questions)	(For contract questions only)
AF00T002 thru AF00T010 AF00T012 thru AF00T020	Air Force Office of Scientific Research AFOSR/NI 4040 N. Fairfax Dr., Ste 500 Arlington VA 22203-1613 (Victoria Franques, (703)696-7313)	Anne Carroll (703) 696-5983

AIR FORCE FY2000 STTR TOPICS

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH, ARLINGTON VA

AF00T002	In Situ Evaluation of Composite Structural Performance in Presense of High Stress/Strain Gradients
AF00T003	Criteria Management System for Multi-Objective Optimization Guided Design of Sequences of Materials Processes
AF00T004	Next Generation, Polymeric-based Nanostructured Materials
AF00T005	Micro-Discharge Devices and Applications
AF00T006	High Frequency Vortex Generation for Active Flow Control
AF00T007	Controller Synthesis for Micro Electro-mechanical Systems (MEMS) Aerodynamic Sensor/Actuator Arrays
AF00T008	Chemical Propulsion for Microsatellites
AF00T009	Coated High Temperature Superconductors (HTS) for Power Systems
AF00T010	Processing of Affordable Advanced Ceramics for Hyper-Temperature Applications
AF00T012	Implementation of Biomimetic Precison Flight in Autonomous Air Vehicles
AF00T013	Heat Reduction in Semiconductors
AF00T014	High Frequency Optical Wavefront Sensors
AF00T015	Automated Location of Structured Expertise in Very Large and Dynamic Information Repositories
AF00T016	Space Ready Polymeric Materials
AF00T017	Terahertz Devices
AF00T018	Pulsed Detonation Propulsion Alternative for Space
AF00T019	Computational Tools for the Sensitivity Analysis and Control of Combustion Instabilities
AF00T020	High-Average-Power, Highly-Efficient, Visible-Wavelength, Solid-State Laser Sources

AIR FORCE FY2000 STTR TOPICS DESCRIPTIONS

AF00T002 TITLE: In Situ Evaluation of Composite Structural Performance in Presence of High Stress/Strain Gradients

TECHNOLOGY AREAS: Materials/Processes, Human Systems

OBJECTIVE: To demonstrate a novel in situ strain measurement techniques for measuring strains in localized regions of textile composites and composite structural joints.

DESCRIPTION: Textile composite preforms are extensively used in many structural components of complex shapes and for low cost processing. Due to complex weaving pattern of the preforms, the deformation behavior and hence the strain field in constituent preform yarns that causes the failure initiation needs to be accurately determined. Surface mount strain gages often fail to capture the critical strain field causing failure. The use of fiber optic strain gages to measure in situ strains within textile reinforcements (both impregnated and unimpregnated) potentially will provide strain field at the unit cell level. The measurement of strain field within the reinforcement will provide an accurate means of validating failure models. Further, these fiber optic strain gages also provides a means to determine strain field in composite joints (bolted and bonded joints) near material discontinuity. This novel strain measurement technique would provide new and unique data by which material models can be validated and (perhaps) the effect of damage on stress/strain fields can accurately be assessed for textile composites and composite joints.

PHASE I: Demonstrate processing of fiber optic sensors within reinforcement of woven composites. The processing is to include weaving of the sensors into the reinforcement for different weaving architectures, such as, plain weave, 5HS, 8HS fabrics. Develop appropriate data reduction techniques for reducing fiber optic data to strain field.

PHASE II: Validate the strain measurement technique with a predictive model for measuring in situ strains for textile preforms and its composites. Textile preforms are to include woven and braided reinforcement architectures, both balanced and unbalanced reinforcements. Demonstrate the capability of the strain measurement for measuring strains in embedded reinforcement at high strain gradients of bolted and/or bonded joints.

PHASE III DUAL USE COMMERCIALIZATION: Fabric and textile preforms, in addition to Air Force's systems, are extensively used in many commercial structures for low cost processing. A prime example is the containment ring for turbine engines. A successful implementation of this in situ measurement technique will validate failure theories, and thus textile composites will be applied in many commercial and military primary structures and efficient composite joints will be designed with increased confidence.

REFERENCES:

1. A. Skontorp, Effect of Embedded Optical fibers on Structural Integrity of Composites, Proc. of ICCM-12, Paris, July 4-9, 1999
2. A. K. Roy, In Situ Damage Observation and Failure in Model Laminates Containing Planar Yarn Crimping of Woven Composites, Mechanics of Composite Materials and Structures, Vol. 3, No. 2, 1996, pp. 101-117.
3. A. K. Roy, Three-Dimensional Mixed Variational Micromechanics Model for Textile Composites, Proceedings of the 39th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Long Beach, CA, April 20-23, 1998.

KEYWORDS: Composite, Structural Performance, High Stress/Strain Gradients

AF00T003 TITLE: Criteria Management System for Multi-Objective Optimization Guided Design of Sequences of Materials Processes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop visual and computational techniques that can be used in coordination with mathematical design optimization algorithms and process simulation methods to assist in the judicious management of objectives and constraints during the design of sequences of manufacturing processes.

DESCRIPTION: In order to more effectively address affordability requirements of Air Force systems, especially in the areas of materials processing and manufacturing, consideration of the entire production sequence during all design phases, rather than just one process at a time, is required. Because of the number of decision variables, nonlinear dynamical nature of materials processes, and complex interactions among the processes in a sequence, the only practical way to achieve near optimal designs is to use mathematical optimization techniques combined with coupled, computer simulations of the processes. While significant progress has been made in recent years in the analytical development of simulation tools and optimization algorithms, little or no effort has been invested in trying to address the primary obstacle to using such systems in an industrial environment: the ability to effectively communicate to the user/designer the relationship among the various objectives and constraints (such as cost, timing, product quality) and the impact of potential tradeoffs among these design criteria, i.e., the ability to manage the design criteria in a formal optimization environment. The lack of this ability leads designers to perform their own non-optimal tradeoff studies by varying the decision variables using intuition ("twiddling") rather than performing optimal tradeoff studies by varying design criteria or studying algorithm-generated design alternatives ("thinking"). By making simulation-based, optimization-guided design standard industrial practice rather than an academic exercise, significant reductions in cost can be achieved by using the optimal tradeoff studies that can be achieved early in the system acquisition when most of the cost is committed.

There are three overall project objectives. The first is the development of computational and visual techniques for presenting information concerning the relationships among large numbers of decision variables and design criteria to designers and for determining the impact of changing either the variables or the criteria. Second is the creation of a comprehensive software framework for integrating these new design tools with existing mathematical optimization algorithms and process simulation techniques. Last is the demonstration of the effectiveness of this framework through application to process design problems relevant to the Air Force: e.g., forging, casting, heat treatment, coating processes, etc.

Specific performance objectives of the proposed effort are:

PHASE I: 1) Using existing state-of-the-art optimization algorithms and appropriate materials and process simulation tools as a basis, develop prototype computational and visual techniques for communicating the complex relations among numerous (greater than 3) design objectives, constraints, and decision variables to designers. 2) Demonstrate the effectiveness of the prototype approach through application to a process design problem of limited complexity.

PHASE II: Based upon the assessed level of effectiveness of the techniques developed 1) improve the techniques through interaction with important Air Force parts and systems suppliers; 2) develop a comprehensive, extensible software framework for integration of optimization techniques, process modeling and simulation tools, and high dimensional visualization techniques; and 3) demonstrate effectiveness through application to a design problem of moderate to high complexity.

COMMERCIAL POTENTIAL: Commercial application is very broad, including DoD OEM's and their suppliers as well as the automotive industry. Application areas include the processing of bulk materials (forging, extrusion, etc.) and thin-film coating processes (pulsed-laser-deposition, chemical-vapor-deposition, etc.), and processes common to both areas such as heat treatments.

REFERENCES:

1. Fiacco, A.V., Introduction to Sensitivity and Stability Analysis in Nonlinear Programming, Academic Press, 1983

2. Greenberg, H.J., "An Annotated Bibliography for Post-solution Analysis in Mixed Integer Programming and Combinatorial Optimization," Advances in Computational and Stochastic Optimization, Logic Programming, and Heuristic Search, D.L. Woodruff (ed.), Kluwer Academic Publishers, Boston, 1998, p. 97-148

3. Miettinen, Kaisa, Nonlinear Multiobjective Optimization, Kluwer Academic Publishers, Boston, 1999

4. Mistree, Farrokh & H.M. Karandikar, "Conditional Post-solution Analysis of Multi-objective Compromise Decision Support Problems," Engineering Optimization, Vol. 12, 1987, p. 43-61

AF00T004 TITLE: Next Generation, Polymeric-based Nanostructured Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop fabrication and processing technologies for polymeric-inorganic nanostructured materials

DESCRIPTION: Commercial and academic interest in nanostructured materials is rapidly growing1. In these materials, the fundamental length scale of the morphology approaches the critical length scale of various physical phenomena, leading to physical and chemical behavior dramatically different from that observed in their bulk and microscale counterparts. In addition, properties associated with the interface between constituents become prominent as the total interfacial area increases with finer phase dimensions. These factors afford the opportunity to combine physical properties and create multifunctional materials not possible with conventional composites and filled systems comprised of microscale constituents. Nanostructured materials, in which polymers are a major constituent, are especially exciting because of the potential to exploit the inherent processing advantages and low-cost economics of polymers. Some examples of recent inorganic-polymeric nanostructured blends included polymer-layered silicates nanocomposites, Polyhedral Oligomeric Silsesquioxane (POSS) containing polymer blends, high-performance conducting fibers, photorefractive hybrids, carbon nanotube blends and nanoparticlate blends. The polymer layered silicate nanocomposites2 are an excellent example in which the addition of less than 4 vol% of dispersed, high aspect ratio inorganic sheets results in the enhancement of large number of physical properties, including mechanical (modulus, strength, thermal expansion coefficient), barrier, flammability resistance, ablation performance, environmental stability, and solvent uptake.

Performance, cost and weight constraints associated with future Air Force space and aerospace operations necessitate the development of new material with unique and tailorable properties that can enable a single component to perform diverse functions. Polymeric-based nanostructured materials are emerging as a family of materials to enable this 'multifunctionality.' New, economically viable fabrication and processing techniques are sought which enable production of monolithic (50 microns or greater) shapes of new-types of polymeric-based nanostructured materials.

PHASE I: Development of a polymeric-inorganic nanostructured material system. Emphasis will be placed on inorganic-polymeric nanostructured materials, which combine superior mechanical properties (modulus and toughness relative to the neat resin), with enhanced barrier and chemical stability; enhanced electrical and thermal conductivity; and/or novel nonlinear optical properties.

PHASE II: Select the material systems with the most promising combination of physical properties, and further developed techniques necessary for the reproducible fabrication of commercially viable specimens in the form of films, fibers and molded components.

PHASE III DUAL USE COMMERCIALIZATION: Commercial applications would include structural components in automobiles, replacement of current filled polymer systems in automobiles, replacement of conventional fiber composites such as fiber glass, and packaging materials such as films and containers for foods which require low permeability and recyclablity. Application in commercial and AF systems would include cryogenic storage tanks, low-observable systems and satellite communication

REFERENCES:

1. Global Assessment of R&D Status and Trends in Nanoparticles, Nanostructured Materials, and Nanodevices, International Technology Research Institute, Loyola College in Maryland, Baltimore, MD.
2. Modern Plastics, June 1999, 37.
3. R.A. Vaia., J-W Lee, C-S Wang, B. Click, G. Price, Chem. Mater., 1998, 10, 2030-2032.
4. Winiarz, J.G.; Zhang, L.; Lal M.; Friend, C.S.; Prasad, P.N. J. Am. Chem. Soc., 1999, 121, 5287.
5. Pileni, M.P. Langmuir, 1997, 13, 3266.

KEYWORDS: Polymeric-based Nanostructured Materials

AF00T005 TITLE: Micro-Discharge Devices and Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: To explore and develop devices for applications of the recently discovered unusual light emitting properties of micro-discharges.

DESCRIPTION: Recently micro-fabrication techniques have been applied to producing micro-discharges based on miniaturized hollow cathodes. These novel discharge structures can operate in a regime of power deposition rate in discharge-excited gases that differs significantly from those pertaining to bulk discharges or larger hollow cathode discharges. Such structures could be of significant interest in making powerful and inexpensive lighting sources, or in creating plasma's for chemical production useful for bulk gas processing or trace chemical agent removal. They could be the basis of optical diagnostics that could be integrated with micro-electronic systems to incorporate optical systems in a "laboratory on a chip." The potential for inexpensive mass fabrication would make such a laboratory on a chip potentially suitable for incorporation in the monitoring and control of combustion systems. Arrays of micro-discharges could provide short wavelength pump radiation for short wavelength lasers, or could, potentially, be locked together to make lasers directly. This STTR effort seeks innovation in the application of micro-discharges in areas such of visible, UV, or IR light sources or lasers, optical diagnostics, inexpensive chemical or surface processing by deep UV radiation or plasma processes, or the integration of micro-discharge technology to make other useful sensors or systems.

PHASE I: Prove in the laboratory a key aspect of the concept for a significant application of micro-discharges. This initial effort should also define the needed steps for fabrication or materials needed for the micro-discharges, as well as examine the integration of the micro-discharge technology with other elements of the entire system.

PHASE II: Development of a laboratory prototype system that could be scaled or further integrated in the Phase III, non-STTR activity. Uses in military applications might include materials processing, plasma- or ultraviolet based remediation of contaminated air, paint removal, or chemical agent detection in point or mobile sensors.

PHASE III DUAL USE COMMERCIALIZATION: Civilian applications include sensors for industrial control and pollution systems, chemical processing and novel light sources.

REFERENCES:

1. J. W. Frame and J. G. Eden, "Planar Microdischarge Arrays", Electronics Letts., 34, 1529 (1998);
2. J. W. Frame, P. C. John, T. A. DeTemple, and J. G. Eden, "Continuous-Wave Emission in the Ultraviolet From Diatomic Excimers in a Microdischarge", Appl. Phys. Lett. 72, 2634 (1998);
3. J. W. Frame, D. J. Wheeler, T. A. DeTemple, and J. G. Eden, "Microdischarge Devices Fabricated in Silicon", Appl. Phys. Lett. 71, 1165 (1997)

KEYWORDS: Micro-Discharge Devices/Applications

AF00T006 TITLE: High Frequency Vortex Generation for Active Flow Control

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Develop high bandwidth mechanical devices for separation control on military air vehicles flying at transonic conditions.

DESCRIPTION: Within the last several years, great strides have been made in active flow control technology for both external and internal flow applications. The work of Wiltse and Glezer [1] on synthetic jets and McManus et al [2] on pulsed vortex generator jets are only two examples of work that has advanced the state-of-the-art in flow separation control. Because of these previous efforts and others, active flow control devices are now being seriously considered for flight validation testing and subsequent military and commercial aircraft fleet applications.

The ongoing research of Seifert and Pack [3] on oscillatory control of flow separation, however, indicates that more effective means of flow control may be at hand if a low cost, reliable oscillatory device can be configured and integrated into an aircraft lifting surface or curved inlet duct. Seifert demonstrated separation control on an airfoil model at Reynolds numbers as high as 13(10)6 and has shown that oscillatory blowing at reduced frequencies in the range of 0.5 to 1.0 is effective over a wide range of Reynolds numbers. If an affordable mechanical device can perform as well as the oscillatory blowing devices of the work described above, then these mechanical devices, being easier to integrate, might be transitioned to real flight vehicles.

PHASE I: Conceptual evaluation of various high frequency mechanical flow control concepts; comparison with oscillatory blowing concepts. Design and bench test "best" concept. Wind tunnel proof of concept test of the "best" concept.

PHASE II: Build a "design tool" for integrating high frequency mechanical flow control actuators for separation control on air vehicles. Large-scale test at transonic speeds.

PHASE III DUAL USE COMMERCIALIZATION: A high bandwidth mechanical actuator will have both the required frequency and displacement necessary for flow control on real systems at real flight conditions. Applications in commercial and AF systems would include: (1) control of flow oscillations in weapons, landing gear, and instrument bays, (2) control of flow separation on control surfaces in military and commercial aircraft, and (3) control of flow-induced noise in turbomachinery and automobiles.

REFERENCES:

1. Wiltse, J.M. and Glezer, A. "Manipulation of free shear flows using piezoelectric actuators (synthetic jets)," J. Fluid Mech., Vol. 249, pp. 261-285, 1993.
2. McManus, K.R., Joshi, P.B., and Legner, H.H., "Pulsed Vortex Generator Jets for Active Control of Flow Separation," AIAA 94-2218, June 1994.
3. Seifert, A. and Pack, L.G., "Oscillatory Control of Separation at High Reynolds Numbers", AIAA-98-0214, Jan 1998.

KEYWORDS: High Frequency Vortex Generation, Active Flow Control

AF00T007 TITLE: Controller Synthesis for Micro Electro-mechanical Systems (MEMS) Aerodynamic Sensor/Actuator Arrays

TECHNOLOGY AREAS: Air Platform, Electronics

OBJECTIVE: Demonstrate the feasibility of synthesizing robust feedback controllers for aerodynamic flows using micro electro-mechanical systems (MEMS) sensor and actuator arrays.

DESCRIPTION: Concepts for using micro sensors and actuators to control flow over aerodynamic surfaces offer the potential of enhanced flight performance for both autonomous and manned air vehicles. Laboratory experiments have demonstrated that micro actuators can yield reduced drag, increased lift, and control of unsteady aerodynamics. These effects could result in extended range, increased flight endurance, reduced fuel consumption, increased control response, and enhanced maneuverability for the next generation of tactical munitions, unmanned air vehicles (UAVs), and manned aircraft. The purpose of this program is to mature new feedback controller synthesis approaches, fundamentally different from synthesis methods currently used for air vehicle flight control system design, which will be required to realize the full benefits of MEMS-based aerodynamic flow control.

The control theory literature abounds with papers on controller design for distributed parameter systems. Most of the techniques involve posing and solving optimal control problems for systems of partial differential equations, based on a variety of assumptions that may or may not be appropriate for this project. A significant portion of the early effort on this project should be directed toward an assessment of the merits and drawbacks of various approaches for producing MEMS-based active aerodynamic flow controllers. It is envisioned that these controllers will be implemented in circuitry that is integrated with the sensor/actuator arrays. Factors to consider include:
> Controller robustness to uncertainties arising from unmodeled dynamics, disturbances, nonlinear actuator interactions, sensor noise, and data latency

> Sensitivity to errors in measurement or estimation of system states or parameters
> Distribution of sensors and actuators
> Complexity of implementing the control scheme

Dynamics models for feedback controller synthesis must be developed from appropriate mathematical models of the local flow conditions, actuator dynamics, actuator interactions, and sensor characteristics. Analytical or empirical data may be used as the basis for these models. Since air vehicles are expected to operate over a range of flight conditions, the models must be valid for variations in velocity, pressure, temperature, and vehicle attitude.

Although the theory for designing controllers for distributed parameter systems is not fully mature, the rapid advances in MEMS technologies will soon make it possible to produce large arrays of micro actuators and sensors with integrated control circuitry. A significant goal of the project is to conduct a hardware demonstration of a candidate robust feedback controller on a prototype MEMS-based aerodynamic sensor/actuator array. Thus, availability of prototype sensor, actuator, and processing hardware, as well as appropriate test facilities, must be considered. In preparation for the hardware test, a preliminary evaluation of the candidate control approach in digital simulation, using models of appropriate fidelity to demonstrate the feasibility of the concept, should be conducted.

PHASE I: Assess the merits and drawbacks of various robust feedback controller synthesis approaches for a MEMS-based active aerodynamic controller. Conduct an evaluation of the most appropriate prototype controllers in digital simulations. Produce a test plan for conducting a Phase 2 aerodynamic flow control hardware demonstration implementing the chosen feedback control approach or approaches.

PHASE II: Refine, as needed, the aerodynamic flow control design concepts and simulations developed in Phase I. Prepare and conduct the feedback control hardware demonstration using a prototype MEMS-based aerodynamic sensor/actuator array. This hardware demonstration will consist of prototype sensor, actuator, and processing hardware in a suitable test facility. Performance and potential benefits of the use of the prototype array configuration will be assessed quantitatively during this hardware in the loop demonstration.

COMMERCIAL POTENTIAL: Successful demonstration of MEMS-based aerodynamic sensor/actuator arrays for flow control will lead to many military and commercial applications. Applications include tactical munitions as well as other aircraft. Reduced Lift/Drag ratios will improve cruise range of a variety of aircraft. Moreover, these arrays can be used to enable agile tactical missiles or fighter aircraft to perform extreme maneuvers under post-stall flight conditions. Use of these arrays to augment the performance of conventional aerodynamic surfaces will allow commercial or military transport aircraft to fly below current stall speed, enabling them to utilize shorter runways for takeoff and landing.

REFERENCES:

1. Paganini F. and Bamieh B., “Decentralization Properties of Optimal Distributed Controllers”, Proceedings of 37th IEEE CDC, Dec. 1998.
2. King B.B. and Sachs E.W., “Semidefinite Programming Techniques for Reduced Order Systems with Guaranteed Stability Margins: A Numerical Study”, Virginia Tech ICAM Report, No. 98-10-01.
3. Orlov Y. and Bentsman J., “Adaptive Distributed Parameter Systems Identification with Enforceable Identifiability Conditions and Reduced Order Spacial Differentiation”, Proceedings of 37th IEEE CDC, Dec. 1998.
4. Padhi R. and Balakrishnan S.N., “Adaptive-Critic Based Optimal Control Design for Distributed Parameter Systems”, submitted to 2000 American Control Conference, June 2000.

AF00T008 TITLE: <u>Chemical Propulsion for Microsatellites</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Investigate and develop chemical-propellant-based concepts that would provide high thrust and high velocity impulse maneuverability for microsatellites. The scope of the work includes the identification of high-performance propellants and the evaluation of relevant issues associated with using such propellants in micropropulsion systems.

DESCRIPTION: The Air Force envisions many missions that would benefit from small, low-cost satellites operating either autonomously or as an element in a cluster of such vehicles. For this purpose, microsatellites are defined as spacecraft having mass between 10 and 100kg. Whereas the continuing miniaturization of electronic components has provided for a sharp reduction in the payload mass necessary to perform a particular mission, the requisite micropropulsion systems have not yet been developed. Energy dense propellants are a requirement for microsatellites, to reduce the mass associated with propellant storage and to maximize their useful lifetimes, and advanced chemical propellants are sought for missions requiring high thrust and high velocity impulse. Various reduced-toxicity, high-energy-density (by comparison with N2114 or MMH/N204) chemical mono- and bipropellants have advanced from the research laboratory to the developmental testing stage. However, it is becoming apparent that traditional catalyst, catalyst bed, combustion chamber, and exhaust nozzle materials cannot withstand the higher temperatures associated with more energetic propellants. Monopropellant formulations containing high concentrations of energetic salts, for example, can have decomposition temperatures in excess of 2500 K. In addition to the materials considerations, there are problems associated with propellant flow, mixing, and combustion in propulsion systems with small characteristic length and volume scales. Clearly, there is a need to design a micropropulsion system that addresses the issues associated with the combustion or decomposition of high-energy-density chemical propellants.

PHASE I: Identify the materials and other design and engineering difficulties associated with using high-energy-density chemical mono- or bipropellants in a micropropulsion system. Particular attention should be paid to materials that can withstand the higher combustion temperatures associated with energetic propellants. The preliminary design of a micropropulsion system is the expected deliverable of Phase I.

PHASE II: Construct and demonstrate a prototype of the micropropulsion system designed in Phase I. This would include test firings with high-energy-density chemical propellants to determine the viability of the design.

PHASE III DUAL USE COMMERCIALIZATION: Microsatellites, with micropropulsion being the enabling technology, are proposed for several military applications, and they would also be expected to have many commercial customers.

REFERENCES:
1. Cort, Robert, et al., "Non-toxic On-orbit Propulsion for Advanced Space Vehicle Applications," AIAA paper 95-2974, July 1995.
2. Walls, T. T., et al., "Performance and Safety Aspects of Monopropellant and Non-toxic Bipropellant Liquid Divert/ACS Propulsion for Navy Theater Ballistic Missile Defense Applications," AIAA paper 93-2634.
3. Huribert, E., et al., "Nontoxic Orbital Maneuvering and Reaction Control Systems for Reusable Spacecraft," J. Propulsion Power, 14 (5), 676, 1998.

KEYWORDS: Chemical Propulsion, Microsatellites

AF00T009 TITLE: Coated High Temperature Superconductors (HTS) for Power Systems

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Understand and exploit relations between processing parameters and resulting mechanical, electrical and magnetic properties to produce an innovative coating technology that will yield uniformly high critical-current density over kilometer lengths while maintaining structural integrity and long-term stability in the range of liquid-nitrogen temperatures.

DESCRIPTION: Superconducting (HTS) generators and motors are expected to provide the most compact, efficient power delivery to air- and ground-based weapons systems currently being designed. As a result, AFRL's Directed Energy Weapons Directorate has declared superconductive materials as an enabling technology. The key to a successful coated HTS conductor technology is a thorough understanding and control of the entire coating process [1,2]. Phase 1 will involve an evaluation of existing coating technologies and of existing methodologies to characterize the quality of conducting tapes produced by existing processes. Beyond the evaluation process itself, preliminary conductor fabrication and characterization efforts should be launched to investigate directly how to advance the state of the art. Consideration should be given to both chemical and physical deposition methods for deposition of a buffer and of YBCO (the acknowledged best HTS material for generating optimum critical currents in a magnetic field environment). Additional considerations may include replacing a textured buffer layer with a high-conductivity normal metal, and how the entire coating process may be accomplished without degradation of the superconductive (YBCO) layer. This phase 1 effort (and phase 2 if it is awarded) should be coordinated with ongoing studies at Wright-Patterson AFB – contact Dr Paul Barnes (barnespn@possum.wpafb.af.mil).

PHASE I: Evaluate existing HTS coated conductor technologies and perform limited studies to develop one or more promising fabrication techniques to produce long lengths of rugged HTS coated conducting tapes with high critical-current density in relevant magnetic fields at or near liquid-nitrogen temperatures.

PHASE II: Perform controlled, small-sample fabrication studies to develop an optimum set of processing parameters for one or more fabrication technologies. Characterization tools are likely to include electron microscopy and magneto-optic imaging. When the most promising processing technology has been determined, scale up the length of coated conductor to at least one meter and check for uniformity over the entire length of specimens produced. Ensure that a process producing high-quality coated superconductive tape can be scaled to 1-km lengths of this quality, and fabricate a prototype tape at least 10 m long.

COMMERCIAL POTENTIAL: A successful coated HTS conductor technology would impact almost all Air Force and other DoD power generation, storage and conditioning systems. It would have an even greater impact on this nation's electrical utility industry and those manufacturing industries that depend most sensitively on reliable and stable electric power. Among the most important commercial applications are motors and generators, superconductive magnetic energy storage systems, high-power transformers, fault current limiters, uninterruptable power supplies and high-power transmission lines [3].

REFERENCES:
1. 1999 Wire Development Workshop Proceedings, DoE publication available from Energetics, Inc., 501 School St., SW, Suite 500, Washington DC 20024 (audrey_lamanna@energetics.com)

2. Proceedings of 1998 Applied Superconductivity Conference, published as June 1999 issue of IEEE Transactions on Applied Superconductivity.
3. "Power Quality, Superconducting Magnetic Energy Storage Systems, and Fault Current Limiters," M. Parizh and E. Leung in Applications of Superconductivity, H. Weinstock editor (Kluwer, Dordrecht 1999).

AF00T010 TITLE: Processing of Affordable Advanced Ceramics for Hyper-Temperature Applications

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop novel approaches toward affordable processing of non-oxide ceramic structural materials for hyper-temperature applications, in the range of 2,000 to 3, 000 C.

DESCRIPTION: This announcement seeks to advance the state-of-the-art of processing non-oxide ceramic materials for hyper-temperature applications, in the range of 2,000 to 3, 000 C. In particular, it concentrates on novel, economical technologies for fabricating hafnium carbide (HfC), titanium carbide (TiC), titanium and zirconium di-borides (TiB2, ZrB2) and other ceramic materials capable of retaining good mechanical properties and exhibiting low ablation rates at the extreme temperatures. The critical research and development areas to be addressed are: (1) The role of additives on the oxidation resistance of refractory carbides and borides; (2) The effects of solid solutions and eutectic microstructures on strength; (3) The development of affordable processing and manufacturing technology to fabricate dense, near-net-shape ceramic components; (4) In situ characterization of the morphology of the materials during testing at elevated temperatures and using these data for life-prediction of the ceramic components;
The advances in these technologies should lead to fabrication of affordable materials for the next-generation of rocket engines and hypersonic spacecraft capable of operating at temperatures in excess of 2000 C with vital Air Force and dual-use applications.

PHASE I: Develop the relationship between composition, microstructure, processing, properties, and performance (life-prediction) of a selected hyper-temperature material system. The selected system should be of major importance to the Air Force program on rocket propulsion or hypersonic air-spacecraft applications (this is one of the evaluation criteria). Optimize processing of the material system and provide measurements of strength, fracture toughness, creep resistance, and environmental stability for the selected system. The aim of the Phase I is to establish a sufficient database for estimating the economics of manufacturing parts from the selected material and the probability of success for introducing this material into Air Force applications

PHASE II: Phase II STTR efforts should take the developments of Phase I and design, develop, and manufacture a prototype. This prototype does not have to be up to the flight specifications level, but should clearly show the potential to meet mutually agreed operational specifications established by an Air Force contractor. Thus the Phase II has three deliverables, the prototype with appropriate characteristics, the established relationship with an Air Force supplier, and the demonstration of future potential improvements in reliability, affordability, performance, and other parameters important for the Air Force.

COMMERCIAL POTENTIAL: By developing an affordable hyper-temperature material system with temperature capabilities of 2000 – 3000 C, the necessity of engine cooling can be significantly reduced, resulting in cleaner burning rocket engine. Thus, fuel utilization can be vastly improved, more payload can be sent to space, higher specific impulse can be achieved and the cost of the rocket engine can be reduced with major impact on military and civilian space technologies.

REFERENCES:
1. “Materials for Ultrahigh Temperature Structural Applications”, K. Upadhia, et al,
Am. Cer. Bulletin, December 1997.
2. “Oxidation Behavior of Hot-Pressed TiC-ZrB2, TiC-HfB2, Si6-ZrB2 Composites”, G. Mehrota, et al, Thermal Analysis in Metallurgy, ed. by B. Shull, The Minerals,
Metals, and Materials Society, 1992.
3. “Ablation Resistant Zirconium and Hafnium Ceramics”, US Patent # 5,750,450

AF00T012 TITLE: Implementation of Biomimetic Precision Flight in Autonomous Air Vehicles

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Demonstrate the use or incorporation of insect neurobiology or sensory processing into the design of precision flight capability of autonomous air vehicles.

DESCRIPTION: The purpose of this project is to develop and demonstrate guidance, navigation, and control (GNC) sensors, components, and/or systems that will enable an autonomous small air vehicle to search for, detect, pursue, and rendezvous with an evasive target in a densely cluttered environment. Success of this endeavor would enable meaningful application payoff in autonomous munitions as well as miniature / small autonomous reconnaissance aircraft. There are both military and civilian (e.g., search and rescue) applications for this capability. The technology required to enable these autonomous precision flight capabilities are based in GNC systems that exploit an extreme complexity and functional interdependency of sensors, processing, flight control, and propulsion; current GNC system design methods are inadequate for the task. For this reason, flying insect neurobiology (e.g., insects in the orders Odonata, Diptera, or Coleoptera) are inspirational for successful designs and configurations of these GNC systems.

The literature on flying insect neurobiology abounds with papers describing the ways insects process information from various sensors to achieve precise navigation and flight. Insects integrate information from inertial sensors (halteres in Diptera, the connection between the thorax and large head of Odonata), air flow sensors (small hairs on the body and head, and Johnston's organ on antennae), internal strain sensors (campaniform sensilla at the base of wings and halteres), and position sensors between adjacent body parts (proprioceptors) with information from the compound eyes (e.g., imaging, optic flow) and ocelli (light intensity) for precision navigation and flight through complex environments. A significant portion of the early part of this project should be devoted to identifying models from insect neurobiology that are suitable bases for GNC system design. With inspiration from these models, a GNC system design is to be developed for a suitable air vehicle prototype. Desirable characteristics of the GNC system include:

1. tolerant to transient sensor information distortion or obscuration,
2. capable of obstacle avoidance (e.g., buildings or trees, power lines or overhanging branches),
3. detection, acquisition, tracking, and guidance to a moving target in background clutter,
4. precision rendezvous with the target (e.g., warhead event, electronic tagging) flight control robustness to wind gusts, turbulence near structures, and
5. complexity of implementing the GNC scheme.

Rapid advances in micro sensor, micro actuator, and processing technologies will soon make it possible to produce small air vehicles that are physically capable of precision flight. The design of GNC systems to exploit the potential capabilities of this hardware is critical to realizing precision flight autonomously. Although the knowledge base of insect neurobiology is quite large, insect biomimetics, especially as applied to aerospace operations, is a relatively immature field. GNC system designs based on insect biomimetics have yet to be demonstrated. Thus, a significant goal of the project is to conduct a demonstration of a candidate GNC system in a prototype sensor hardware-in-the-loop test. For this reason, availability of prototype sensor, actuator, and processing hardware, as well as appropriate test facilities, must be considered. In preparation for the hardware test, a preliminary evaluation of the candidate control approach in digital simulation, using models of appropriate fidelity to demonstrate the feasibility of the concept, should be conducted.

PHASE I: From suitable insect neurobiology candidate models, demonstrate that a GNC system for autonomous precision flight is feasible from a biomimetics standpoint. Conduct an evaluation of a prototype biomimetic-GNC system in a digital simulation. Develop a test plan for conducting a Phase II sensor hardware-in-the-loop demonstration.

PHASE II: Refine the biomimetic-GNC system design tested in Phase I for more extensive sensor hardware-in-the-loop testing. Further demonstrate the feasibility of this approach. Prepare and conduct a demonstration using prototype sensor hardware in a suitable hardware-in-the-loop facility.

COMMERCIAL POTENTIAL: Air vehicles capable of autonomous precision flight would have several commercial and military customers. Applications would include small surveillance and reconnaissance aircraft as well as AF unmanned air vehicles (UAVs), and tactical munitions.

REFERENCES:
1. Hengstenberg, R.., "Multisensory Control in Insect Oculomotor. Systems," in Visual Motion and its Role in the Stabilization of Gaze, Elsevier Science Publishers B.V, 1993.
2. Srinivasan, M.V. et al., "IJoneybee Navigation en Route to the Goal: Visual Flight Control and Odometry," J Exp. Bin! Vol. 199,2513-2522,1996.
3. Strausfeld, N. J., "Oculomotor Control in Insects: From Muscles to Elementary Motion Detectors," in Neurons, 'Vetworks, and Motor Behavior, MIT Press, 1997.
4. Fayyazuddin, A., and Dickinson, M., "Haltere Afferents Provide Direct, Electronic Input to a Steering Motor Neuron in the Blowfly, Calliphora," J Neuroscience, Vol.16, number 16, 5525-5232, 1996.
5. Burrows,, M., The Neurobiology ofan Insect Brain, Oxford University Press, 1996.
6. Srinivasan, M. V., and Venkatesh, S., From Living Eyes to Seeing Machines, Oxford University Press, 1997.
7. Corbet, P. S., Dragonflies: Behavior and Ecology of Odonata, Cornell University Press, 1999.
8.Kamioer, A., "Flying," in volume 5, Nervous System; Structure and Motor Function, of Comprehensive Inseer Physiology Biochemistry and Pharmacology, Pergamon, 1985.Topic Author-Johnny Evers

AF00T013 TITLE: <u>Heat Reduction in Semiconductors</u>

TECHNOLOGY AREAS: Information Systems, Electronics

OBJECTIVE: Find a way to use confined phonons to form coherent waves that can then be annihilated with a second stimulated wave of the opposite phase, possibly using pairs of quantum wells, for example. This has the potential to significantly reduce the cooling requirements of semiconductor lasers and detectors.

DESCRIPTION: Annihilation of phonons close to the active region of a laser would allow significantly higher pumping levels and power output for lasers used for infrared countermeasures. Lower noise detectors would also be enabled by this technology, increasing the sensitivity and reducing the weight for spaceborne platforms.

PHASE I: Experimental evidence of phonons confined by a quantum well points out the potential to advance cooling technology. Modeling would be required to predict which material system could exhibit desirable characteristics of phonon lifetime, mode occupation, etc. Modeling should examine various material systems, e.g. heterojunctions, quantum wells with any of the available band alignments, metal layers, etc.

PHASE II: Demonstrate lasers with power output greater than a factor of ten higher, long wavelength infrared detectors with no external cooling requirements.

PHASE III DUAL USE COMMERCIALIZATION: The expense and size of cooling is presently preventing the infrared spectrum from being used in many commercial applications including automotive, manufacturing, and medical.

REFERENCES: 1. "Phonon confinement in InAs/GaSb superlattices", D. Berdekas, G. Kanellis; Physical Review B, volume 43, number 12, 9976-9979 (1991).
2. "Electrophonon resonance in cylindrical quantum wires", S. Yu, V. Pevzner, K. Kim, and M. Stroscio; Physical Review B, volume 58, number 7, 3580-3583 (1998).
3. "Confined optical phonons in the AlAs layers of GaAs/AlAs superlattices", V. Haisler, D. Tenne, N. Moshegov, A. Toropov, I. Marakhovka, and A. Shebanin; JETP Letters, volume 61, number 5, 376-380 (1995).

KEYWORDS: Semiconductors

AF00T014 TITLE: High Frequency Optical Wavefront Sensors

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop and demonstrate an improved high frequency two-dimensional optical wavefront sensor.

DESCRIPTION: Optical wavefront sensors are used to measure wavefront aberrations for a variety of applications. In adaptive optics systems, this information may be used to impose a conjugate wavefront on a deformable mirror. In other applications, this information may be used as a diagnostic tool to characterize the temporal and spatial aberrations arising from a turbulent flow process. Hartmann wavefront sensors are limited in their bandwidth by the frame-rate of CCD arrays and the post-processing algorithms applied to the collected frames. High frame rate CCD cameras can be costly components in these sensors, and the highest frame rate cameras typically do not provide a continuous throughput of frames. Lateral effect detectors have a higher bandwidth response and can provide continuous output, but do not provide a two-dimensional characterization of the wavefront. An ideal wavefront sensor would have high frequency response (50 kHz or more), high resolution (30 by 30), continuous output, and low cost.

PHASE I: Conceptually design the wavefront sensor and analyze the performance of the wavefront sensor using appropriate design tools. Demonstrate the operation of critical components in bench-level demonstrations.

PHASE II: Build and test a working prototype of system proposed in Phase I. Test and demonstrate the operation of the prototype in appropriate government, commercial or university laboratory setups. Characterize the frequency response and resolution of the wavefront sensor.

PHASE III DUAL USE COMMERCIALIZATION: An improved wavefront sensor will find application as a critical component in adaptive optical systems for military imaging systems. It will likely also find application in medical imaging systems, optical communications, and as a research tool for optical diagnostics.

REFERENCES:
1. Shack, R.V., and Platt, B.C., "Production and use of a lenticular Hartmann screen," Journal of the Optical Society of America, 61, 655, 1971.
2. Petersson, G.P., and Lindholm, L.E., "Position sensitive light detectors with high linearity," IEEE Journal of Solid-State Circuits, Vol. SC-13, No. 3, June 1978.
3. Tyson, R.K., "Principles of Adaptive Optics," Academic Press, Inc., Boston, 1991.
4. Malacara, D., "Optical Shop Testing, 2nd Ed," John Wiley and Sons, Inc., New York, 1992.

KEYWORDS: Optical Wavefront Sensors

AF00T015 TITLE: Automated Location of Structured Expertise in Very Large and Dynamic Information Repositories

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Demonstrate that structured information can be located automatically in very large and dynamic information repositories, using concepts from data mining, and artificial intelligence.

DESCRIPTION: More and more information is available on-line, which makes the task of organizing information quite daunting. The clearest example of this is the common frustration with the overload of unstructured information provided by search engines. Although search engines for on-line information are improving rapidly, much less attention is being paid to the question of how to uncover the hidden structure of information sources. A similar need for uncovering structure in information sources exists in large military operations, e.g., air campaign planning, that involve large numbers of documents in a relatively unstructured form.

The goal of this effort is to develop automated tools to locate and structure information on a particular topic. These tools should incorporate methods for data mining of on-line information sources to uncover the underlying structure of the information on a topic, its ontology and network of experts associated with the information. Searches for people and information can be structured according to relationships (for example, social or scientific relationships: find papers by colleagues of a well-known expert), as opposed to the flat, unstructured model used by current information retrieval engines.

An automated information and expertise locator system will be of value to the Air Force by facilitating the flow of information within the large highly distributed organization. Especially, given the dynamic nature of the Air Force organization, with people and units moving around frequently, dynamic tools for information location throughout the organization will be of significant value to the Air Force. The system can cover areas of technical expertise, for example, all information on air campaign planning for a certain region, as well as expertise involving organizational and management structure. Furthermore, it can be set up as an informal tool for providing crucial introductory information to new recruits or re-located personnel.

PHASE I: Phase I will investigate the development of data mining and information retrieval tools for locating information and uncovering its hidden structure in large information repositories.

PHASE II: Build and test a working prototype of system proposed in Phase I.

PHASE III DUAL USE APPLICATIONS: Phase III will test and evaluate tools for information discovery and structure identification in very large information repositories and commercialize results of Phase I and II. Accessibility to structured information increases choices for consumers in both civilian and defense application. This technology could have a major impact on applications that require the rapid integration of large amounts of information, such as needed in integrated decision making and timely and accurate information such as planning and scheduling systems and personnel military command and control. There is also significant commercial potential given the importance of large repositories of information such as the World Wide Web.

REFERENCES:
1. "Recommender Systems", Paul Resnick and Hal R. Varian (Eds.) Communications of the ACM (special issue),Vol.40, No.2, March 1997.
2. "Intelligent Agents", Doug Riecken (Ed.), Communications of the ACM, Vol.37, no.7, July 1994.
3. "Foreword: On the barriers and future of knowledge discovery", G. Wiederhold, Advances in Knowledge Discovery and Data mining, AAAI/MIT Press, 1996.

AF00T016 TITLE: <u>Space Ready Polymeric Materials</u>

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: This STTR topic will seek research on polymeric materials designed for space applications. The research will also include the investigation of properties of these materials relevant to space applications.

DESCRIPTION: Lightweight is a critical parameter for space applications. Polymeric materials are lightweight and mechanically robust, making them ideal materials for space applications. Polymers can be used as matrix resins in fiber reinforced composite structures in satellites, liquid fuel tanks components in launch vehicles, and membranes in inflatable large space structures. With the advancement of polymers in electronic and photonic applications, this class of materials is also considered for non-structural applications in space. With some advanced concepts for future space structures, multifunctional structures that can serve both structural and functional purposes are envisioned. Unreinforced polymers can also be considered for future miniturized space platforms such as the Microsats. This topic will seek research that can lead to development of “space-ready” polymeric material systems. Focuses will be on the durability of these materials in space application related environments. These will include, but not limited to, atomic oxygen and debris effects in low earth orbit for structural components, other radiation effects in higher orbits for photonic and electronic applications, and cryogenic temperature behavior in liquid fuel tank applications. Research on better understanding the material behavior in these environments with a clear connection to a material development effort in a later phase is acceptable.

PHASE I: Propose innovative chemical structures and/or chemical design concepts for space applications. Demonstrate appropriateness of these structures or design concepts for space applications.

PHASE II: Develop the proposed material technology and conduct appropriate testings to validate the appropriateness of the proposed chemical structures and/or chemical design concepts for space applciations and progress towards commercial development of these chemical structures or concepts.

COMMERCIAL APPLICATIONS: Commercial space applications in communications, environmental sensing and weather monitoring.

REFERENCES:

1. D. J. Kessler, R. C. Reynolds and P. D. Anz-Meador, Orbital Debris Environment for Spacecraft Designed to Operate in Low Earth Orbit", NASA-TM 100471, 1988.
2. E. M. Silverman, "Space Environmental Effects on Spacecraft: LEO Materials Guide, NASA Report 4661, Part I, p. 1-47.

AF00T017 TITLE: Terahertz Devices

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Development of solid state terahertz devices for operation in the range between 0.3 Thz to 10 Thz that are suitable for coherent sources and detectors for use in space-based and short range terrestial communications, atmospheric sensing, and near object analysis.

DESCRIPTION: The electromagnetic spectrum from 300 Ghz to 10 Thz is scientifically rich but relatively technologically poor. The region represents a gap separating electronics oriented towards transport, from photonics oriented toward quantum transistors. Devices that mix quantum and transport physics will fill this void. The region offers the potential for a number of applications including space-based and short-range terrestrial or near earth communications, atmospheric sensing, collision avoidance for aircraft and ground vehicles, and near object observation and spectroscopy. To realize this potential the appropriate sources, detectors, and systems need to be developed.

Innovative approaches are needed leading to the development, fabrication, and operation of coherent solid state terahertz sources. Efforts may include electrically excited devices as well as those driven by solid state optical lasers. Three terminal devices, and classical approaches, such as Gunn diode oscillators may be considered as long as proper power and efficiency advances are addressed. Highly desired are approaches in quantum wells and tunneling devices, as well as other novel quantum structure approaches. The goals of this effort are devices and device concepts that will deliver coherent radiation at potentially milliwatt power level, ultimately coupled efficiently in Thz circuits, guided wave structures and antennas.

Work is needed in detectors to greatly improve the sensitivity, speed, and bandwidth. Specifically desired are efforts in semiconductor-based quantum well structures and the subsequent development of a useable detector that is narrow band, widely tunable, and yet highly sensitive. Other solid-state approaches may be considered. Approaches toward compact system modules addressing both generation and detection are also of interest.

PHASE I: Clearly demonstrate the feasibility of the proposed approach. Define device that will deliver up to milliwatts of coherent radiation at specified frequencies in the Thz regime, and/or define the detector or detector structure detailing optimal geometry, bandwidth limitations, tunability, and current-carrying capacity. The definition of the device/ system-module needs to include principal of operation, material, processing, associated circuit or guided wave structure, and regime of operation.

PHASE II: Build upon Phase 1 work and demonstration of system components and implementation of a prototype. Perform appropriate analysis and modeling, grow the material or structure, fabricate the device and test its performance.

PHASE III DUAL USE COMMERCIALIZATION: Terahertz electronics and photonics have many potential applications. Covert communication on the battlefield or in space, chemical agent detection, atmospheric environment sensing, near object detection, material imaging will benefit from new technology in this part of the electromagnetic spectrum. New terahertz electronics will also make possible ultra high speed signal processing.

REFERENCES:

1. "Photon-assisted tunneling in a resonant tunneling diode: Stimulated emission and absorption in the THz range," Hermann Drexler, Jeff Scott, S.J.Allen Jr, K.L. Campman and A.C. Gossard; Applied Physics Letters, Volume 67, 4102 (1995)
2. "Inverse Bloch Oscillator: Strong Terahertz-Photocurrent Resonances at the Bloch Frequency"; K. Unterrainer, B.J. Keay, M.C. Wanke, S.J. Allen, D. Leonard, G. Medeiros-Ribeiro, U. Bhattacharya, and M.J.W. Rodwell; Physical Review Letters, Vol. 76, 2973-6 (1996).
3. "Transition from classical to quantum response in semiconductor superlattices at THz frequencies" , S. Zeuner, B.J. Keay, S.J. Allen, K.D. Maranowski and A.C. Gossard, U. Bhattacharya and M.J.W. Rodwell; Physical Review-B Rapid Communications, B53, R1717 (1996).
4. Terahertz links on the web: http://www.bell-labs.com/user/igal/thzlinks.htm
5. C. Waschke, H. G. Roskos, R. Schwedler, K. Leo, H. Kurz, and K. Koehler, Phys. Rev. Lett. 70, 3319 (1993).

KEYWORDS: Terahertz Devices

AF00T018 TITLE: Pulsed Detonation Propulsion Alternative for Space

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: The objective of this topic is to develop a concept for a pulsed detonation rocket engine suitable for space propulsion applications. Potential space applications for pulsed detonation propulsion include boost, upper stage, orbit transfer, divert, station keeping, and attitude control. Micropropulsion concepts will also be considered.

DESCRIPTION: In a pulsed detonation rocket engine (PDRE), a charge of propellants is introduced into a combustion chamber and allowed to premix. The mixture is then detonated, and impulse is gained from the event from the pressure built up on the back walls of the combustion chamber. Repetition rates reaching 140 Hz have been achieved for GH2/GOX systems. Because detonation waves travel at thousands of meters per second, combustion is completed as something close to a constant volume process. The higher peak temperatures and pressures reached as a result can result in better performance than a conventional constant pressure device with the same feed system. An additional advantage of the pulsed detonation cycle stems from the fact that the combustion chamber pressure is low (near ambient) when the propellants are injected. In conventional rocket cycles, elevated pressures (reaching 3,500 psi in the space shuttle) are required in the combustion chamber in order to achieve adequate thrust. Large pumps are needed to inject the propellants against these pressures. The pulsed detonation cycle potentially reduces the pumping requirements significantly. This in turn considerably reduces the weight of the propulsion system and potentially improves its simplicity. It has been estimated that eliminating the turbopumps from the space shuttle main engine would reduce its weight by 24%, improve reliability by 27%, and reduce hardware costs by 20%. These are extraordinarily large numbers for a rocket propulsion system. Other advantages of the pulsed detonation cycle include the ability to throttle deeply and the potential to deliver impulse bits more precisely than competing cycles.
Numerous technical challenges will need to be overcome before PDRE's can be fielded, many of which, for instance the practical requirement to use liquid phase fuels, will be common to airbreathing applications. However, space propulsion introduces a number of unique additional challenges. For instance, as the ambient pressure approaches a vacuum, the potential performance advantages will probably not be as significant as at atmospheric pressure, although the potential to operate at lower feed system pressures remains. Filling the chamber and achieving detonations when the ambient pressure is a vacuum needs to be addressed, as well as materials compatibility and pre-ignition issues arising from the hotter operating temperature of a rocket. Space propulsion applications may offer unique opportunities as well, such as the opportunity to operate using oxidants other than air and the potential economies of using fuels and oxidants which are both in the liquid state.

PHASE I: A successful phase I effort will develop a PDRE concept for one or more of the space propulsion applications identified above. Technical challenges which need to be overcome to achieve the concept will be assessed, and plausible approaches to overcome the challenges will be identified. Modeling, experimentation, or both can be used to assess the concept. Suitable analysis will also be conducted to clearly demonstrate how the PDRE concept would be superior to existing or other possible ways to accomplish the selected mission.

PHASE II - A successful phase II effort will develop the concept into a working prototype which will demonstrate the performance of the concept.

COMMERCIAL POTENTIAL: Currently there is enormous commercial potential in space, and a PDRE concept with demonstrable superior capability for one or more of the above space propulsion applications would find a market in the commercial launch and satellite business. Further market opportunities would arise if the concept also has potential for airbreathing applications.

REFERENCES:

1. Kailasanath, K. "Applications of Detonations to Propulsion: A Review," 37th AIAA Aerospace Sciences Meeting and Exhibit, paper AIAA-97-1067, Reno, NV, 11-14 January 1997.
2. Bussing, T., and Pappas, G., "An Introduction to Pulse Detonation Engines," AIAA Paper 94-0263.
3. Cambier, J.-L., and Tegner, J.K., "Strategies for Pulsed Detonation Engine Performance Optimization," Journal of Propulsion and Power 14(4), pp 489-498,

AF00T019 TITLE: Computational Tools for the Sensitivity Analysis and Control of Combustion Instabilities

TECHNOLOGY AREAS: Air Platform, Information Systems, Space Platforms

OBJECTIVE: Develop computational tools for time accurate sensitivity analysis of combusting incompressible flows with finite rate chemistry. The tools must be suitable for use in design, optimization, and active control of combustors.

DESCRIPTION: Requirements for recently developed military engines have lead to increases in engine pressure ratios and fuel loading. These increases typically produce more instances of combustion instabilities. A similar trend can also be seen in industrial power generation gas turbines due to low NOx requirements at both full and partial power conditions. Such instabilities can be directly related Low and High Cycle Fatigue in gas turbines. One approach to meeting new engine performance and maintenance requirements is to use modern optimization and control techniques to mitigate these combustion instabilities while maintaining required performance levels.

Historically, passive approaches have been applied to mitigate combustion instabilities. These attempts at attenuating instability were typically very costly in both man-years and dollars. The solutions were also very condition specific. Currently, active combustion control is being employed to control instabilities in basic and applied research settings. This approach is also being considered on industrial power generation gas turbines in the United States and abroad. A fundamental problem is the development of tools, which allow one to intelligently evaluate whether active or passive techniques are more suitable for a given design setting. Tools for the evaluation of the performance and correctness of implementation of various methodologies are needed. Incorrect answers can produce added expense to engine development, procurement, and operation and maintenance costs. A predictive capability is required to assess the sensitivity of combustion instabilities to various engine parameters. In addition, design tools are needed to optimize and control such systems.

Accurate determination of numerous parameter sensitivities is essential. Some important parameters, which need to be considered are turbulent length and time scales, chemical kinetic time scales, droplet spray and atomization time and length scales, geometry, sensor type, sensor placement, fuel and air actuation type and placement. Since active control is an important component of this work, time accurate design and simulation tools must be developed.

PHASE I: Develop steady state methodology to predict the sensitivity of the parametric factors, which contribute to the dynamic instabilities of combustion processes, which typically occur in gas turbine combustion systems. This methodology must be validated by comparison with available data.

PHASE II: Develop a time accurate methodology for computation of time dependent parameter sensitivities. Develop tools, which can be used to design, optimize, and, implement both passive and active controllers. Issues such as sensor and actuator placement and system performance must be addressed.

PHASE III DUAL USE COMMERCIALIZATION: Currently, there is a strong need for an accurate modeling capability for gas turbines; both military and industrial. These new computational tools will be beneficial in reducing development, operation, and maintenance costs, through optimization and control of instabilities.

REFERENCES: [1] Rayleigh, J. W. S., "The Theory of Sound", Vol II, Dover, NY, 1945
[2] Kim, Y. M., Chen, C. P., and Ziebarth, J., "Vaporization Effects on Combustion Instability of Liquid Fueled Engines", ICLASS-99, Washington D.C., 1991.
[3] Schadow, K. C., Gutmark, E., and Parr, D. M., "Large Scale Coherent Structures As Drivers of Combustion instability", Combustion Science Technology, VOL 64, Nos 4-6, 167-186, 1989
[4] Godfrey, A., Eppard, M., and Cliff, E., "Using Sensitivity Equations for Chemically Reacting Flows", AIAA-98-4805 , St. Louis, MO.

KEYWORDS: Computational Tools, Sensitivity Analysis, Control of Combustion Instabilities

AF00T020 TITLE: High-Average-Power, Highly-Efficient, Visible-Wavelength, Solid-State Laser Sources

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Develop a compact and efficient (continuous-wave or continuous-wave-modelocked) laser source with more than 100 W average output power tunable in the visible spectrum.

DESCRIPTION: The Air Force and DOD have numerous requirements for moderate to very high average power lasers, in space, airborne, and ground-based applications. Examples include weaponry, illumination, imaging, and remote detection of chemical and biological threats. At the present time, laser systems are individually developed, and are generally too costly and unreliable for most potential uses. An approach to this problem would be to develop generic laser systems which could be put together to get necessary power levels, and use nonlinear optical and other techniques, as necessary, to achieve necessary wavelengths and other characteristics. At the present time fiber, rod, and slab lasers based on such materials as Nd:YAG, Nd:YVO4, and Yb:YAG have reached average power levels at hundreds of watts at wavelengths near 1 micrometer. These lasers may be useful pump sources for nonlinear conversion to visible wavelengths. However, the optical power handling capabilities of current nonlinear optics (NLO) materials are often limited due to thermal effects caused by optical absorption. These effects become even more extreme at short (i.e., visible) wavelengths. Thermal-management techniques developed for laser-head cooling may be applicable to current NLO materials. Such use of advanced cooling concepts in NLO materials may enable higher output powers than is currently possible. The goal of this STTR topic is to design and demonstrate the feasibility of a compact, efficient, high-power, visible-output, solid-state laser/NLO light source.

PHASE I: Design and test feasibility of compact, efficient, high-power infrared laser source and NLO converter for generating tunable visible output wavelengths at the 100 Watt or greater levels.

PHASE II: Develop and test prototype of the concept(s) developed in the Phase I effort.

PHASE III DUAL USE COMMERCIALIZATION: The laser sources developed under this topic will have value to commercial manufacturers of displays, printers, adaptive optics systems and laser machining equipment. Ultra small systems meeting the criteria would have several commercial and military customers.

REFERENCES:
(1) W. F. Krupke, "High-Average-Power, Quasi-Three-Level, Diode-Pumped Solid State Lasers", Proceedings of the Conference on Lasers and Electro-Optics, Technical Digest Series, vol. 6 (1998);
(2) G.D. Miller, R.G. Batchko, W.M. Tulloch, D. R. Wiese, M. M. Fejer, and R. L. Byer, "42% Efficient Single-Pass CW Second-Harmonic Generation in periodically Poled LiNbO3", Opt. Lett. 22, 1834-1836 (December 1997)

KEYWORDS: High-Average-Power, Visible-Wavelength, Solid-State Laser Sources